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ORIGINAL MEMOIRS.

END-TO-END ARTERIOVENOUS ANGEIORRHAPHY*

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ABOUT a year ago, on learning of the work of Carrel and Guthrie of Chicago, with their remarkable and interesting experiments in angeio-anastomosis, the idea occurred to me that in a case of impending gangrene of an extremity, due to interference with the arterial blood-supply, an arrest of the necrotic process might be possible by diverting the arterial current into the veins. The conditions in which I judged that an experiment of this kind would be justified were the following: (1) Threatened gangrene due to embolism; (2) Threatened gangrene due to thrombosed aneurism; (3) Threatened gangrene due to traumatism, with great destruction of arterial tissue; (4) Malignant neoplasm involving important arteries (so that extirpation would threaten the vitality of the part; (5) Angeiosclerotic gangrene.

In Mt. Sinai Hospital the cases of gangrene due to angeiosclerosis far outnumber those due to all the other causes combined; so it seemed to me that my first case would probably be drawn from this class. To be sure, it is well known that in this disease the walls of the veins as well as those of the arteries are thickened, narrowing or even closing the vascular lumen, but the changes in the venous trunks and their tributaries occur later and are apt to be less marked than those in the arteries. Having once averted the gangrene, it was my hope that by general treatment a return of the trouble might be long deferred, or possibly, even prevented.

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I began looking about for a case suitable for a pioneer operation, always bearing in mind the maxim "non nocere." My prospective patient must have the disease in such a form that manifestly nothing short of a major amputation would save his life and yet the gangrene must not have progressed so far that a re-establishment of the circulation might not save the remainder of the limb. Several patients with angeiosclerotic gangrene presented themselves at the hospital, but before consent could be obtained amputation became necessary. Then, in April, 1906, a young man was admitted who appeared to be a promising subject. During the time of the preliminary treatment, before angeio-anastomosis had been decided upon, I was fortunate enough to meet Dr. Carrel, who called upon me at the hospital, and I then had the privilege of hearing an accurate description of the operative technique from his lips. This proved to be of inestimable value.

The patient, W. W., entered one of my wards on April 26, 1906. He was twenty years of age, a native of Russia, and a salesman by occupation. With the exception of a chronic gonorrhœa of six years' duration, his history was unimportant up to the time of his vascular trouble, the symptoms of which began several months before I saw him. There was pain and burning in the calves of the legs, gradually increasing in severity until walking became impossible. Two months before admission a painful ulcer developed on the dorsum of the left great toe, the pain extending to the other toes and finally to the entire leg and thigh up to the groin. Another ulcer now appeared on the heel, with dusky red patches on the front of the ankle.

The physical examination was negative as to eyes, ears, nose, mouth, pharynx, glands, lungs, heart, radial pulses, liver, spleen, abdomen and rectum. Slight mucous chronic urethral discharge. General condition was good in spite of a rather marked anæmia. On the inner side of the terminal phalanx of the left great toe there was an ulcer larger than a thumbnail, its outline sharply defined, its edges raised and in part undermined, its floor covered by sloughy granulations discharging thin serous fluid. At the apex of the left heel was a similar ulcer, slightly larger than the one on the toe, its base gangrenous and black. Dusky patches on the point of breaking down were seen on the dorsum of the foot near the ankle. These ulcers and their neighborhood were intensely painful and extremely tender to the slightest touch. The left dorsalis pedis artery could not be felt nor could the left popliteal. Pulsation at the femoral was very faint. The right dorsalis pedis and femoral pulsated normally. The diagnosis of arteriosclerotic gangrene was made and treatment begun with the administration by mouth of glonoin, iodide of potassium, and with mercury by inunction, in the hope that there might be an underlying syphilitic element, even in the absence of its history. On May 16 Dr. B. Sachs saw the patient and concurred in the diagnosis,

In spite of treatment the disease continued to progress, the ulcers became larger, the foot dusky and the threatening area on the dorsum exulcerated. A few inflammatory glands could be felt in the left groin. The general condition of the patient greatly deteriorated and he and his family at length realizing that probably nothing short of amputation could be of avail, consented to a preliminary operation on the blood-vessels as a forlorn hope. It was my intention to anastomose the upper end of the severed popliteal artery with the lower end of the severed popliteal vein, closing by ligation the proximal end of the vein and, if necessary, the distal end of the artery.

On June 2, under gas and ether, I made an incision only to find that the popliteal artery was absolutely obliterated and also its continuation upward as far as could be ascertained through a seven-inch incision. The operation was abandoned and the wound closed by suture.

Four days later, June 6, the operation was performed upon the vessels in Scarpa's triangle. Carrel advises the employment of extremely fine milliner's needles and silk. In his experiments upon animals he uses needles as fine as No. 16, the eye of which is almost microscopic in size. The mere threading of these needles is no easy task. The finest needle I was able to procure was No 12, and with this I used white 000 silk. The needles were sterilized by boiling in the usual way, the silk by heating it in the sterilizer with vaseline. This silk is put into the vaseline *dry*, so that when the proper degree of heat is reached the entire texture of the thread becomes impregnated with the fat. The needles were threaded and ready before the operation began. In this work a needle holder cannot well be used, and a thimble is necessary in operating upon the thick walls of the larger vessels. A supply of thin tape or "bobbin" was sterilized and ready to be used as temporary ligatures which were not to be tied but held in position by small artery forceps or a spring clamp (*serre fine*). No Esmarch's bandage or other general constrictor should be used. Every necessary adjunct to the most perfect asepsis was employed, but no chemical antiseptics were permitted about the wound.

A four-inch incision crossing Poupart's ligament and running approximately in the line of the femoral vessels exposed these structures to view. A few femoral and inguinal lymph nodes, somewhat enlarged because of the infection in the foot, had to be removed. The exposure of the parts was easy and was very perfect. It was then observed that pulsation of the femoral artery existed only in the uppermost portion of that vessel, so that the anastomosis would have to be made with the upper portion of the vein, above the saphenous tributary. The return flow of the circulation in any event could hardly be through the obliterated arteries, which had remained closed even against the systolic pressure of the left ventricle, but it was hoped that blood for tissue nutrition would be carried through the venous capillaries and that it would find its way back through the gluteal, obturator and other veins, as I had observed in cases of thrombosis of the femoral or even of the external iliac vein.

The vessels were laid completely bare for about two inches and femoral pulsation was controlled by a tape ligature clamped around the external iliac artery. A loosely knotted piece of catgut was also placed around this artery to be used in case of the accidental slipping of the tape. The vein was now permanently ligated at the same level as the temporary arterial ligature, and was temporarily ligated below. My object was to allow for the contraction of the severed vessels, so as to avoid tension at the proposed anastomosis. The artery was then severed about a centimeter below the point of intended anastomosis, and the vein about the same distance above it. After section it was found that this precaution had been a wise one, the mouths of the vessels being easily brought together. There was no hemorrhage. Each vessel had been cut across so as to form a stump of about 2 cm. in length, and the lumen of each of these stumps, especially that of the vein, was carefully emptied of residual blood by gentle manipulation of the vessel walls, and was then filled with sterile vaseline as advised by Carrel.

The vascular suture was performed as follows: A stitch was passed and tied, fastening the two mouths together. At a distance of one-third of the circumference from this first suture, another "anchor" suture was passed, and then a third, so that the sutures marked the angles of an equilateral triangle within the circle of the vascular lumen. The ends of the sutures were left long to permit their being used as retractors. Each stitch was passed directly through all the coats of the vessels in such a manner as to avoid the *turning in* of the walls, but rather to evert them ever so slightly to insure the contact of the intimas. By traction upon the anchor sutures, two at a time, the contiguous parts of the vascular walls were rendered straight and parallel. A running suture was passed along each side of the triangle and was tied to the anchor suture as soon as the angles were reached, so as not to break the continuity of the junction. By careful handling of the anchor sutures the vessels (vein and artery) were rotated around the longitudinal axis, bringing within easy reach that side of the triangle which was being sutured. The previous thorough dissection rendered this very easy. Just before the last running suture was tied to its anchor the vessels were emptied of vaseline by gentle manipulation. The final knot being tied, the tape compressing the femoral artery was removed, and at once the pulsating current was established from artery to vein without the suspicion of leakage. Pulsation was marked in the visible part of the femoral vein and could be felt, though intermittently and with some difficulty in the external saphenous. Carrel states that in the larger vessels of dogs it takes about 20 minutes for the arterial blood to force the venous valves. In this case no pulsation of any of the veins of the foot was noted, but from the ulcers, which at the beginning of the operation were markedly cyanotic and did not bleed, bright red blood began to exude.

Within ten minutes the foot appeared to have recovered somewhat from the intense cyanosis incident to the ligation of the femoral artery, but it never even approached the normal in color. The wound was sutured and dressed dry, the entire limb splinted and slightly flexed at the hip, and carefully covered with a thick elastic layer of non-absorbent cotton. The entire operation consumed about 50 minutes. The patient's condition at its termination was one of shock, though practically no blood had been lost. Pulse 150°, weak and irregular. This shock continued and deepened. By the next morning the pulse was hardly perceptible. Very little urine had been passed—albuminous, with hyalogranular casts—and altogether the patient's condition was such as to forbid anything excepting general stimulation, which was most energetically carried out.

Eighteen hours after the completion of the operation a distinct line of demarcation had formed, crossing the upper portion of the dorsum of the foot, thence up the sides of the leg and crossing the calf about seven or eight inches above the point of the heel. This entire area was now obviously without circulation: cold, numb and gangrenous. Above this line, however, there was fair circulation and the patient easily located a pinprick. Pulsation could not be felt in the saphenous vein.

The profound shock was not easy of explanation. To be sure, there had been a severe disturbance of his circulatory apparatus, but this would also have been the case had I amputated. Indeed, I had intended to amputate in the event of the failure of the angeiorrhaphy, but this plan had to be abandoned because of the shock. Death occurred 31 hours after the operation, following an ante-mortem rise of temperature to 105°. It is my belief that any radical operation would probably have been followed by a fatal result, and that the death should not be ascribed to the angeiorrhaphy.

A post-mortem examination to ascertain the cause of death was most unfortunately refused, so it was possible only to secure the specimen of vein and artery taking in the anastomosis.

This showed a smooth union with an extremely soft clot in the vein—possibly formed just before death, when the circulation was at its lowest ebb. There was not the slightest hæmorrhage, bulging of the vascular walls or other indication of a giving way under the arterial pressure.

In spite of the failure of this operation we may study its various phases with profit.

In the first place, we must recollect that the condition for which it was undertaken is absolutely hopeless so far as saving the limb is concerned. Amputation either well below the knee or at midthigh is the usual form of successful treatment, the osteoplastic operation having yielded in my experience the best results. Yet, sloughing of the flaps with re-amputation is common enough and the post-operative mortality due to the general vascular disease is high.

In the experiments of Carrel, the subjects being healthy animals, a complete reversal of the circulation of the extremity was possible, but in cases of arteriosclerotic gangrene the most that could be hoped for would be the carrying of arterial blood for tissue nourishment through the less diseased vessels, the veins, and back again through other veins—return flow through the diseased and obliterated arteries being obviously out of the question. Actual experiment alone could demonstrate the practicability of this operation, and since in the above case the anastomosis had to be made so high in the main vascular trunks, the matter has not been decided. Had it been possible to work with the popliteal vessels, as originally planned, more light would have been thrown upon this important point.

In threatened gangrene due to embolism of arteries distal to a main trunk, the promise of success seems to me good. For example, in embolism of the popliteal artery, end-to-end anastomosis of superficial femoral artery with the saphenous vein might re-establish a circulation in the affected part, averting the necrosis. Practically nothing would be lost in the event of failure. This procedure might also be tried in cases of thrombosed aneurism of the popliteal artery.

In destruction of a portion of the main artery by traumatism or because of the implication of its walls in an otherwise operable malignant growth, a resection of the artery with interposition of a piece of vein might be practised.

The work in angeiosclerotic gangrene should be continued, but more and more favorable cases should be selected for experiment.

One point demonstrated by this operation is that the danger of immediate traumatic aneurism following the implantation of artery into vein in the human subject, has been overestimated.

NOTE.—The case here reported is probably the first in which artery has been anastomosed with vein without a corresponding counteranastomosis of vein into artery. After my paper had been presented I learned of the case of Dr. Joshua C. Hubbard, of Boston, who had operated for gangrene about one month before my operation, and who had attempted to accomplish complete reversal of the circulation according to Carrel's suggestion, but without employing his methods. Dr. Hubbard was fortunate enough to secure an operative recovery, though without curing the gangrene. The limb had to be amputated. His case was published in the ANNALS OF SURGERY for October, 1906.

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